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configured to determine the mass of the substance, the amount of change in the reference resonant frequency being indicative of the mass of the substance.

REMARKS

The applicants appreciate the Examiner's thorough examination of the application and requests reexamination and reconsideration of the application in view of the preceding amendments and the following remarks.

The Examiner objects to the disclosure because of an informality on page 11, line 2 with the reference to the word “it”. In response, as shown above under AMENDMENT A, the applicants have removed the word “it” from the disclosure.

The Examiner rejects claim 23 under 35 U.S.C. §112, first paragraph. The Examiner states that claim 23 contains subject matter which was not described in the specification in such a way to enable one skilled in the art to which it pertains, or which it is most nearly connected, to make and/or use the invention. The Examiner states that claim 23 comprises a single means claim. In response, the applicants have amended claim 23, to recite “The apparatus of claim 1 in which the mass determining device measures the range in mass of a substance in the subnanogram range”. Accordingly, amended claim 23 is not a single means claim and the Examiner's rejection of claim 23 under 35 U.S.C. §112, first paragraph, is properly withdrawn.

The Examiner rejects claim 11 under 35 U.S.C. §112, second paragraph stating that there is insufficient antecedent basis for “said microprocessor”. In response, the applicants have amended claim 11 to recite “a microprocessor”. Accordingly claim 11 is definite and in accordance with 35 U.S.C. §112, second paragraph, and the Examiner's rejection of claim 11 should be withdrawn.

The applicant acknowledges the Examiner's objections to the drawings as noted on form PTO 948. The applicant will submit formal drawings after the Notice of Allowance is issued.

The Examiner rejects claims 1-3, 5, 7-8, 15, 17-18, and 22-23 under 35 U.S.C. §102(b) as being anticipated by White et al. (U.S. Patent No. 5,218,988). The Examiner alleges that White et al. discloses each and every element of the applicants' claimed apparatus and method for measuring the mass of a substance on a membrane as recited in independent claims 1 and 17.

The truly effective and accurate apparatus and method for measuring the mass of a substance, as claimed by the applicants, includes the unique combination of a sensor having a membrane layer which receives a substance thereon, an oscillator device configured to output a signal which drives the membrane at a reference resonant frequency, a frequency detection device configured to determine the change in the reference resonant frequency caused by the presence of the substance on the membrane, and a mass determining device configured to determine the mass of a substance wherein the amount of change in the reference resonant frequency is indicative of the mass of the substance. The unique apparatus and method as claimed by the applicant is capable of detecting mass changes of the sensor in the picogram range. See applicants' specification, page 12, lines 1-9.

Specifically, the apparatus for measuring the mass of a substance as claimed by the applicants in claim 1 includes: 1) a sensor having a membrane layer, the membrane for receiving the substance thereon; 2) an oscillator device configured to output a signal which drives said membrane at a reference resonant frequency; 3) a frequency detection device configured to determine a change in the reference resonant frequency caused by the presence of the substance on the membrane; and 4) a mass determining device configured to determine

the mass of the substance wherein the amount of change in the <u>reference resonant frequency</u> is indicative of the mass of the substance.

In sharp contrast, White et al. does not teach, suggest, or disclose an oscillator device which is configured to output a signal to drive the membrane at a <u>reference resonant frequency</u>. Instead, White et al. teaches launching Lamb waves from a first transducer which cause a deformation in the piezoelectric layer of the receiving transducer, which then creates an electric signal which is fed back to an <u>amplifier</u> which amplifies the signal to create a sustained oscillation. Moreover, the oscillator of White et al. operates at the frequency of <u>Lamb waves</u>, not <u>the reference resonant frequency</u> of the membrane as claimed by the applicants.

White's teaching and disclosure of the deformation of a piezoelectric layer to produce an electric signal is provided as follows:

> The Lamb waves <u>launched</u> at the transducer 23 propagate along the propagation medium or membrane 22 to the receiving transducer 24 and cause a <u>deformation of the piezoelectric layer</u> 32 at the receiving transducer 24. This wave-induced <u>deformation</u> of the piezoelectric layer 32 <u>causes an electrical signal</u> at the transducer 24, which is representative of the <u>Lamb wave</u> at that point. (Col. 11, lines 60-66, emphasis added).

The signal generated by the deformation of the piezoelectric layer on the membrane of White et al. is then fed back and amplified to create and oscillator that operates at the <u>frequency of the Lamb waves</u>:

> The signal received at the transducer 24 is <u>fed back</u> along the feedback path 26 to the <u>amplifier</u> 25, where the signal is amplified sufficiently to sustain oscillation. The amplified signal is then <u>fed back</u> to the launching transducer 23. The transducers 23 and 24, the propagation medium 22, and the feedback amplifier 25 thus form an oscillator <u>that operates at the frequency of the Lamb waves</u> traveling through the propagation medium 22. For a given Lamb wave mode, such as the zeroth-

> order antisymmetric mode, the frequency response of the amplifier gain determines at which of its possible frequencies the device will oscillate. (Col. 11, lines 11-23, emphasis added).

This teaching is in stark contrast to what the applicants claim. The applicants' claim 1 includes an oscillator device which is configured to output a signal which drives a membrane at a reference resonant frequency, and a unique frequency detection device which is configured to determine the change in the reference resonant frequency caused by the presence of a substance on a membrane. The unique oscillator as claimed by the applicants does not rely on an electrical signal generated by the deformation of a piezoelectric transducer on the membrane which is amplified to create an oscillation. The oscillator device claimed by the applicants in claim 1 outputs a signal which drives the membrane at a reference resonant frequency. The reference resonant frequency is important to the invention because the frequency detection device is configured to measure the change in the reference resonant frequency caused by the presence of a substance on a membrane. The mass determining device then determines the mass of the substance based on the amount of change in the reference resonant frequency which is indicative of the mass of the substance. The mass sensitivity of the claimed apparatus is defined (in light of the specification) by a relationship between the change in the mass and the reference resonant frequency. See applicants' specification, page 11, line 8-page 12, line 11.

In sharp contrast, as noted above, White et al. does not teach, suggest, or disclose an oscillator device which is configured to output a signal to drive the membrane of the sensor at the reference resonant frequency. Instead, White et al. launches a wave at the first transducer which then deforms a piezoelectric layer. This generates a signal that is fed back and amplified to create a sustained oscillation. Further, White et al. does not rely on the reference

resonant frequency of the sensor at all. Instead, White et al. teaches that the oscillator operates at the frequency of the Lamb waves traveling through the propagation medium. Therefore, White et al. actually teaches away from the applicants' claimed oscillator which drives the membrane at a reference resonant frequency and the frequency detection device which determines the change in reference resonant frequency, and the mass determining device which determines the mass based on the amount of change of the reference resonant frequency.

Accordingly, White et al. does not teach, suggest, or disclose each and every element of the applicants' claimed invention as recited in amended claim 1, namely an oscillator device configured to output a signal which drives the membrane at a reference resonant frequency, a frequency detection device configured to determine the change in the reference resonant frequency, and a mass determining device configured to determine the mass of a substance, the amount of change in the reference resonant frequency being indicative of the mass of the substance. Instead, White et al. clearly teaches away from the applicants' claimed invention as recited in claim 1.

Accordingly, claim 1 is clearly allowable and patentable under 35 U.S.C. §102(b) and the Examiner's rejection of claim 1 under 35 U.S.C. §102(b) should be withdrawn. Because claim 17 is a method of measuring the mass of a substance for the apparatus recited in claim 1, claim 17 is also allowable and clearly patentable under 35 U.S.C. §102(b). Further, because dependent claims 2, 3, 5, 7-8, 15, 18, 22, and 23 depend from allowable base claims, claims 2, 3, 5, 7-8, 15, 18, 22, and 23 are clearly allowable and patentable under 35 U.S.C. §102(b).

The Examiner rejects claim 11 under 35 U.S.C. §103(a) as being unpatentable over White et al. The Examiner further rejects claims 8-10, 18-19, and 22 under 35 U.S.C. §103(a) as being unpatentable over White et al. in view of Bowers. The Examiner rejects claim 16

under 35 U.S.C. §103(a) as being unpatentable over White et al. in view of Ballato.

As stated above, White et al. does not disclose each and every element of the applicants' invention as recited in claims 1 and 17. Because claims 8-10, 11, 16, 18-19, and 22 depend from an allowable base claim, claims 8-10, 11, 16, 18-19, and 22 are allowable and patentable under 35 U.S.C. §103(a).

To advance prosecution, the applicants have added claims 24 and 25.

New claim ~~25~~ 24 recites, in part: "an oscillator device connected to a first transducer disposed on said membrane for driving said membrane at a reference resonant frequency; a frequency detection device connected to a second transducer disposed on said membrane for determining the change in the reference resonant frequency caused by the presence of substance on the membrane" (Emphasis added).

White et al. does not disclose, teach, or suggest an oscillator device connected to the first transducer disposed on the membrane of the sensor. White et al also does not disclose, teach, or suggest a frequency detection device connected to the second transducer on the membrane. Instead, White et al. discloses a frequency counter (e.g. a frequency detection device) connected to the first transducer and an oscillator device connected between the first and second transducers.

New claim 25 recites in part: "an oscillator device connected to a first transducer disposed on said membrane, the oscillator device configured to output a signal which drives said membrane at a reference resonant frequency; a frequency detection device connected to a second transducer disposed on said membrane, the frequency detection device configured to determine a change in the reference resonant frequency caused by the presence of a substance on the membrane".

In sharp contrast, there is no disclosure, teaching, or suggestion in White et al. that the

oscillator is configured to drive the membrane at a reference resonant frequency and which is connected to a first transducer disposed on the membrane. Further, there is no disclosure, teaching or suggestion in White et al of a frequency detection device connected to a second transducer disposed on the membrane. Instead, as stated above, White et al. teaches the use of Lamb waves propagated through a medium which deforms a piezoelectric transducer on the sensor to produce a signal which is fed back and amplified to create an oscillating circuit which is disposed between the first and second transducers, and a frequency detection device which is connected to the first transducer on the membrane of the sensor.

Accordingly, new claims 24 and 25 are clearly patentable.

Each of the Examiner's rejections has been addressed or traversed. Accordingly, it is respectfully submitted that the application is in condition for allowance. Early and favorable action is respectfully requested.

If for any reason this Response is found to be incomplete, or if at any time it appears that a telephone conference with counsel would help advance prosecution, please telephone the undersigned or his associates, collect in Waltham, Massachusetts, (781)890-5678.

Respectfully submitted,

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Fig. 14 is a graph that shows the relationship between the frequency of the sensor and the temperature of a substance when determining the boiling point of the substance;

Fig. 15 is a flowchart of the operation of the fourth embodiment of the present invention; and

Fig. 16 is a schematic diagram of an array of sensors in accordance with the present invention.

PREFERRED EMBODIMENT

Mass measuring system 10, shown schematically in Fig. 1, includes a flexural plate wave sensor 12 including a membrane 14, a first transducer 16 and a second transducer 18, both disposed on membrane 14. An oscillator 20 is connected to transducer 16 for driving the membrane at a reference resonant frequency. Transducer 18 receives this frequency and transmits it to a microprocessor 22 which includes a frequency detection device 24 and a mass determining device 26. An optional display 28 may be connected to the microprocessor 22 for displaying the values determined by the system 10.

As shown in Figs. 2 and 3, sensor 12 includes a structural layer 30 which is preferably formed from undoped silicon, a lower layer 34 which is preferably formed from boron-doped silicon and a piezoelectric layer 36 which is preferably formed from a piezoelectric material such as aluminum nitride. Sensor 12 includes a cavity 38 (shown in phantom in Fig. 2) which is etched into the upper layer 32 and structural layer 30, leaving lower layer 34 exposed within the cavity. The exposed portion of lower layer 34 forms the membrane 14 of the sensor 12. Transducers 16 and 18 are preferably interdigitated transducers.

In operation, oscillator 20 causes transducer 16 to transmit a wave at a reference

frequency in the direction of arrow 42 which wave is received by transducer 18. The wave received by transducer 18 is transmitted to frequency detection device 24 of microprocessor 22. Generally, as long as the mass per unit area of the membrane 14 does not change, the reference frequency input by transducer 16 and received by transducer 18 remains constant. However, when the mass per unit area of the membrane increases or decreases, such as when a substance is deposited or removed from the membrane, a frequency shift in the wave received by the transducer 18 results.

The amount of the change in the frequency within the membrane 14 is inversely proportional to the change in the mass on the membrane 14. For example, as shown in Fig. 4, if the mass of the membrane 14 is at a steady state and the reference frequency is 10MHz, an increase in the mass of the membrane by an amount Δm causes the frequency in the membrane to decrease to 9.85 MHz. By knowing that the frequency of the membrane has decreased by 150 Hz, the change in the mass of the membrane can be determined. The relationship between the mass change Δm and the frequency change Δf is shown in the graph of Fig. 5. The mass sensitivity, S_m, of the sensor 12, which defines the relationship between the mass and frequency changes, is determined using the following equation:

$$S_m = \frac{(\Delta f / f_{ref})}{(\Delta m / A)}, \qquad (1)$$

where f_{ref} is the reference resonant frequency input to the membrane through transducer 16 and A is the area of the membrane, which in the preferred embodiment is 5.0 mm^2. Accordingly, the mass sensitivity S_m is determined by driving the membrane 14 at a reference resonant frequency, placing a substance of a known mass, Δm, on the membrane and measuring the change Δf in the reference resonant frequency. The relationship between

Applicant: Williams et al.
For: Apparatus and Method for Measuring the Mass of a Substance

(Once amended)

1. An apparatus for measuring the mass of a substance comprising:

a sensor having a membrane layer, the membrane for receiving the substance thereon;

configured to output a signal which drives

an oscillator device ~~for driving~~ said membrane at a reference resonant frequency;

configured to determine

a frequency detection device ~~for determining~~ a change in the reference resonant frequency caused by the presence of the substance on the membrane; and

configured to determine based on a

a mass determining device ~~for determining~~ the mass of the substance, ~~the~~

said change in the reference resonant frequency

~~amount of~~ change in the reference resonant frequency, being indicative of the mass of the substance.

2. The apparatus of claim 1 wherein said sensor is a flexural plate wave sensor.

3. The apparatus of claim 2 wherein said flexural plate wave sensor is formed from a silicon substrate and said membrane is formed from a silicon layer.

4. The apparatus of claim 3 wherein said flexural plate wave sensor further includes a piezoelectric layer formed on said membrane, a first transducer disposed on said piezoelectric layer and a second transducer disposed on said piezoelectric layer, spaced from said first transducer.

(once amended)

11. The apparatus of claim 1 further including a display device connected to a ~~said~~ microprocessor for displaying the mass of said substance.

12. The apparatus of claim 1, further including a heating device for heating said substance after it has been deposited on said membrane to evaporate moisture from said substance, said frequency detection device determining the change in the reference resonant frequency after the moisture is evaporated from said substance.

13. The apparatus of claim 12 further including a moisture content determining device;

wherein the mass determining device determines the mass of the substance after the substance is heated and the moisture content determining device determines the moisture content of the substance by comparing the mass of the substance before it is heated to the mass of the substance after it is heated.

14. The apparatus of claim 12 further including a boiling point determining device;

wherein the heating device heats the substance with a temperature which is increasing at a constant rate which causes the reference resonant frequency to increase at a first rate as the mass of the substance decreases;

the frequency detection device monitors the rate of change of the reference resonant frequency as the substance is heated; and

(once amended) of claim 1 in which the mass determining device measures the

23. An apparatus ~~for measuring a~~ change in the mass of a substance within the subnanogram range.